Survey of Northern Abalone, *Haliotis kamtschatkana,* Populations in Queen Charlotte and Johnstone Straits, British Columbia, May 2004

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SURVEY OF NORTHERN ABALONE, *Haliotis kamtschatkana*, POPULATIONS IN QUEEN CHARLOTTE AND JOHNSTONE STRAITS, BRITISH COLUMBIA, MAY 2004.

by

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ABSTRACT

Davies, K., Atkins, M., and Lessard, J. 2006. Survey of northern abalone, *Haliotis kamtschatkana*, populations in Queen Charlotte and Johnstone Straits, British Columbia, May 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2743: iii + 17 p.

A survey was conducted during May 17-20, 2004, in Queen Charlotte and Johnstone Straits to estimate the distribution and density of emergent northern abalone (*Haliotis kamtschatkana*). The estimated mean density for emergent abalone of all sizes was 0.064 ± 0.022 abalone/m^2 in Queen Charlotte Strait and 0.017 ± 0.014 abalone/m^2 in Johnstone Strait. The mean shell length for both areas combined was 85.7 mm. This study was compared to two earlier surveys conducted in 1977 and 1986 in the same area, as well as recent surveys on other parts of the coast.

RÉSUMÉ

Davies, K., Atkins, M., and Lessard, J. 2006. Survey of northern abalone, *Haliotis kamtschatkana*, populations in Queen Charlotte and Johnstone Straits, British Columbia, May 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2743: iii + 17 p.

Un échantillonnage a été effectué dans les détroits de la Reine Charlotte et Johnstone, en Mai 2004, pour estimer les densités et la distribution des ormeaux nordiques (*Haliotis kamtschatkana*). Les densités des ormeaux émergents sont estimées à 0.064 ± 0.022 ormeau/m^2 dans le détroit de la Reine Charlotte et 0.017 ± 0.014 ormeau/m^2 dans le détroit de Johnstone. La longueur moyenne était 85.7mm pour les deux régions échantillonnées. Ce relevé est comparé à deux échantillonnages précédents effectués en 1977 et 1986 dans les même régions, ainsi qu'avec d'autres échantillonnages récents dans le reste de la province.

INTRODUCTION

Northern abalone, *Haliotis kamtschatkana*, generally occur in patchy distributions along exposed or semi-exposed coastlines from Yakutat, Alaska to Baja California (McLean 1966; O'Clair and O'Clair 1998). In British Columbia (BC), abalone were once an important food source of First Nations, and were harvested by recreational and commercial divers. The biology and fishery of the northern abalone were reviewed by Sloan and Breen (1988) and Farlinger and Campbell (1992). Survey results at index sites showed that population densities declined by more than 75% during the period of 1978-90 (Winther et al. 1995; Thomas and Campbell 1996). As a result of these substantial decreases, the Department of Fisheries and Oceans Canada (DFO) banned the harvest of northern abalone due to conservation concerns in December 1990. Since the fishery closure, abalone populations in BC have shown no sign of recovery. In 1999, the northern abalone was listed as '*threatened*' by the Committee on the Status of Endangered Wildlife in Canada (Campbell 2000; Jamieson 2001).

Although other factors may play a role, low recruitment levels and continued harvest despite the fishery closure probably have had predominant and widespread effects, and are considered to be the most significant threats to northern abalone recovery (Abalone Recovery Team 2002). Other threats that could impair the recovery of abalone populations include sea otter predation as well as habitat destruction or alteration due to works and developments in, on, or under water. Knowledge gaps as identified within the Recovery Strategy (Abalone Recovery Team 2002) included a need to clarify the extent to which works and developments on, in and under the water threaten northern abalone and their habitat. The recovery strategy identifies a need for monitoring and regulation of these works and developments in order to maintain an ecosystem in which the northern abalone can be recovered and to prevent losses to important spawning aggregations. For example, the environmental impacts of salmon net-cage farming on nearby abalone populations have never been examined in BC, or anywhere else. As a preliminary assessment, several salmon aquaculture tenures were surveyed in 2004 to determine the presence of abalone populations in close proximity to the net-cage holding systems. Results of this preliminary assessment are presented in this report.

During 1977 to 1990, approximately 102 tonnes of abalone were reportedly harvested from Pacific Fisheries Management Area (PFMA) 12, in which Queen Charlotte Strait and the western portion of Johnstone Strait encompass the majority of potential abalone habitat (Harbo 1997). Considerably more abalone were taken in PFMA 12 than elsewhere on the south coast, but the majority of the landings, while the commercial fishery was opened, were taken from the Queen Charlotte Islands and the north and central coast of BC. As a result of the relatively small amount of abalone reported harvested in PFMA 12, few surveys have been conducted in this area and therefore very little data exist on abalone distribution and abundance in Queen Charlotte and Johnstone Straits. Breen et al. (1978) described a semi-quantitative survey conducted mainly in Queen Charlotte Strait where the survey locations where chosen based on logbook records and other fishers' information. In 2004 we sampled some of these sites which showed the presence of abalone in 1977. Except for one small

location (Breen et al. 1978; Adkins 1996), Johnstone Strait had not been surveyed before 2004.

This report describes an abalone survey conducted in Queen Charlotte and Johnstone Straits to determine abalone distribution and densities. The results are compared between randomly chosen sites, salmon aquaculture tenures as well as sites initially surveyed in 1977 (Breen et al. 1978). The results of this survey may be used in conjunction with other index site survey results in BC to establish baseline abalone abundance data and evaluate the effectiveness of conservation efforts along the coast.

METHODS

SURVEY METHODS

Daily diving operations commenced from the Canadian Coast Guard research vessel 'CCGS Vector'. Two smaller support vessels transported two dive teams to and from the sites for four days in May 2004. Both boats were equipped with a GPS and charts to find the location of each site.

A total of 62 sites were surveyed for the presence of abalone in Queen Charlotte and Johnstone Straits (Fig. 1): nine previously surveyed sites (further referred as index sites; Breen et al. 1978), 16 finfish aquaculture sites and 37 random sites. The index sites were found from previous chart records, written site descriptions and GPS positions. Finfish aquaculture sites were chosen based on abalone habitat found closest to the pen-systems. Random sites were selected without bias using 'Random Points along a Line' an ArcView (ESRI version 3.2) script (Eichenlaub 2000) that randomly placed sites along the shoreline selected. Due to time constraints, only portions of Queen Charlotte and Johnstone Straits were selected to allocate random sites to be sampled. Twenty-five sites were randomly chosen in each of the areas selected (Fig. 1); of these, 13 sites were not surveyed due to unfavourable conditions such as high current or poor abalone habitat (e.g., sand/gravel substrate).

All sites were surveyed using the method described by Breen and Adkins (1979). Once each site was located, divers placed a $1m^2$ quadrat at the top of the abalone habitat zone and then systematically sampled 16 quadrats within a 7m by 16m area (4 rows of 4 quadrats). For each quadrat, divers recorded the dominant algal species and counted urchins, and then cleared the quadrat of all kelp, sea urchins, and sea stars to ensure all exposed abalone were easily detectable. The divers then recorded the number of exposed abalone, shell length (SL in mm), depth, and substrate type. If no abalone were seen by the eighth quadrat, the dive was aborted and the site count was scored as zero.

ANALYTICAL METHODS

Densities were calculated for each site as the number/m^2 for total exposed abalone, as well as for three size categories: immature (< 70 mm SL); mature (≥ 70 mm SL); and large adults (≥ 100 mm SL, formerly the legal size). The smallest size at which

100% of abalone were mature was found to be approximately 70 mm SL (Campbell et al. 1992). Densities of immature abalone could be underestimated due to the difficulty of detecting small individuals (<70mm SL) because of their cryptic nature (Cripps and Campbell 1998).

A one-way ANOVA was used to compare mean shell lengths between Queen Charlotte and Johnstone Straits. As the total exposed abalone density data were not normally distributed, the non-parametric Kruskal-Wallis test was used to compare densities between random, index, and finfish aquaculture sites; if differences were detected at the 0.05 confidence level, a Mann-Whitney U test was used for comparisons between types of sites.

RESULTS

A total of 26 sites were surveyed in Queen Charlotte Strait, including 7 finfish aquaculture sites and 6 index sites; and 36 sites in Johnstone Strait, including 9 finfish aquaculture sites and 3 index sites (Table 1, Appendix 1-2). The majority of sites in both areas were composed primarily of bedrock or boulders with some shell substrate. The primary canopy species of algae encountered was *Nereocystis luetkeana,* understorey species commonly included *Alaria sp, Desmarestia sp, Laminaria sp,* and/or *Agarum sp*, and dominant turf species were articulated corallines and *Ulva* sp. Encrusting coralline algae were found at all sites (Appendix 3). All sites surveyed contained good abalone habitat; there was either (1) an abundance of urchins or (2) the presence of algae usually growing in moderate energy areas or (3) the presence of hard substrate (Appendix 1-3). The majority of the sites had all three combined.

An average of 14.2 minutes (range: 6-33) was spent diving at each random or index site, and 17.0 minutes (range: 10-38) at each finfish aquaculture site (Appendix 1-2). Thirty-seven abalone were found in total; 27 at surveyed sites in Queen Charlotte Strait and 10 in Johnstone Strait (Table 1).

Total exposed density estimates for all sites were 0.064 ± 0.022 abalone /m^2 in Queen Charlotte Strait, and 0.017± 0.014 abalone/m^2 in Johnstone Strait. There was significantly more abalone in Queen Charlotte Strait than in Johnstone Strait (U=341.5, P=0.009). The overall density for both surveyed areas was 0.037 ± 0.013 abalone/m^2. Abalone were found at only 19% of the sites surveyed. In Johnstone Strait, there were significantly more abalone found at the index sites than at either the random or finfish aquaculture sites (U=59.0 and U=4.5, P=0.001 and P=0.011; respectively) (Table 2). There was no difference in abalone density between sites in Queen Charlotte Strait. Density estimates for exposed abalone by size category for each site surveyed are presented in Appendix 4.

The mean size of all abalone found was 85.7mm SL. The size ranges were 43-114mm SL in Queen Charlotte Strait and 90-140mm SL in Johnstone Strait (Fig. 2). The abalone measured in Johnstone Strait were significantly larger than those found in Queen Charlotte Strait (Table 1) (ANOVA, *P*=0.000). In Queen Charlotte Strait, only one abalone surveyed was larger than the historic legal limit of 100mm SL. However in

Johnstone Strait, 60% of the abalone surveyed were large adults (≥ 100mm SL) and no immature (<70mm SL) were observed (Table 1).

DISCUSSION

In Queen Charlotte Strait, abalone densities found at index sites (0.080 abalone/m^2) and random sites (0.024 abalone/m^2) were lower than densities in the immediate vicinity of finfish aquaculture sites (0.125 abalone/m^2), although this difference was not statistically significant (Tables 1 - 2). Surveyed sites at aquaculture tenures were not randomly selected, but were placed at the nearest good abalone habitat found by the pen-system. The higher density estimate at finfish sites could have resulted from a bias in site selection. Nonetheless, it appears that abalone can live in the vicinity of pen-systems as four out of seven tenures surveyed in Queen Charlotte Strait had abalone at the site. The tenures where abalone were found have been in operation since 1991-1995 (M. Ayranto, Pan Fish Canada Ltd, Campbell River, BC, V9W 8C9; pers. comm.) indicating that abalone can survive several years within salmon aquaculture tenures. Previous studies of aquaculture in BC have indicated that the effects of organic waste on benthic fauna were dependant on current velocity, water depth, farm size and depositional environment (Winsby et al. 1996). At salmon aquaculture sites surveyed here, divers noted high current in the area, which can carry waste sediments away from farm sites. Conversely, the tenures where abalone were found in this survey could have been put in areas where abalone were more likely to occur and the abalone sampled in 2004 were the remnants of a larger population. As no data of abalone abundance exist before these facilities were put in operation, the direct impacts of finfish aquaculture on abalone populations cannot be assessed and further research is warranted.

In Johnstone Strait, abalone densities at index sites (0.188 ± 0.157 abalone/m^2) were significantly higher than at random or finfish aquaculture sites, where densities were effectively zero. The random sites surveyed may give a more representative estimate of abalone densities in Johnstone Strait than the index sites, which were originally chosen based on locations where abalone abundance was higher (Breen et al. 1978). All index sites monitored in Johnstone Strait were in one very small area. Previous surveys done in this particular location indicated high abalone density, up to 10 abalone/m^2 based on timed-swims in 1977 (Breen et al. 1978), and 1.13 abalone/m^2 from a 1986 using the Breen survey method (Adkins, 1996). This was the only place in Johnstone Strait where divers surveyed any abalone at all in 2004, save one individual sighted at site R28. Since no previous surveys other than the index site surveys were completed in Johnstone Strait, it is not possible to determine whether abalone densities in this area have declined or have always been low. Harvest logs confirm there were commercially harvestable numbers in PFMA 12 (Harbo 1997), but a survey by Breen et al (1978) suggested that the fishery was largely confined to the north of Port Hardy, where densities were higher. It is doubtful that abalone were ever abundant in Johnstone Strait due to the steep shoreline present throughout which limits the amount of abalone habitat. In addition, reports from fishers, when the commercial fishery was opened, indicated no location where abalone were present at a density making it

worthwhile for fishing. Without a significant population in Johnstone Strait it is unlikely that abalone will dispersed in this area as the surface waters have strong currents with a net flow towards Queen Charlotte Strait and the open ocean (Thomson 1981), possibly preventing larval settlement. All abalone measured were large, indicating that recruitment in Johnstone Strait has not occurred for a number of years.

While there were smaller abalone present in Queen Charlotte Strait (Table 1), the densities have certainly decreased since 1977, although not directly comparable due to differences in survey designs (Breen et al. 1978). The abalone densities estimated from this survey in Queen Charlotte or Johnstone Straits were the lowest observed from similar surveys conducted around the coast of BC in recent years (Table 3). However, they were comparable to a broodstock survey completed within PFMA 12 in 1999 at Malcolm and Cormorant Islands (Lessard et al. 2002) which estimated densities ranging from 0.026 ± 0.005 to 0.050 ± 0.019 abalone/m^2. Abalone densities in tne Queen Charlotte and Johnstone Straits are at levels where the likelihood of recruitment failure is high (Shepherd and Brown 1993, Shepherd and Partington 1995; Babcock and Keesing, 1999; Campbell 2000).

For future surveys, we recommend that all sites surveyed in 2004 within Queen Charlotte Strait be resurveyed, with additional sites selected in other parts of Queen Charlotte Strait and Queen Charlotte Sound.

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Table 1. Abalone count, mean size, and density estimates by size category for Queen Charlotte and Johnstone Straits 2004 survey. Standard errors are in brackets.

Location	Number of Sites Sampled	Number of Quadrats Sampled	Total Abalone Count	Mean Size (mm)	Total Density	Immature (<70mm) Density	Mature (>70mm) Density	Large (>100mm) Density	Percent of Sites with Abalone (%)
Queen Charlotte Strait sites									
Index	6	64	8	70.8 (6.7)	0.080 (0.058)	0.058 (0.047)	0.020 (0.013)	0.010 (0.010)	33.3
Random	13	127	5	88.8 (3.1)	0.024 (0.013)	0.000 (0.000)	0.025 (0.014)	0.000 (0.000)	23.1
Finfish aquaculture	7	88	14	75.9 (4.6)	0.125 (0.056)	0.044 (0.018)	0.081 (0.040)	0.000 (0.000)	57.1
All sites	26	279	27	76.8 (3.4)	0.064 (0.022)	0.025 (0.012)	0.039 (0.014)	0.000 (0.000)	34.6
Johnstone Strait sites									
Index	3	40	9	107.1 (5.5)	0.188 (0.157)	0.000 (0.000)	0.187 (0.158)	0.104 (0.104)	66.7
Random	24	200	1	135.0 (0.0)	0.003 (0.003)	0.000 (0.000)	0.020 (0.020)	0.002 (0.002)	4.2
Finfish aquaculture	9	72	0	n/a	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.0
All sites	36	312	10	109.9 (5.6)	0.017 (0.014)	0.000 (0.000)	0.078 (0.061)	0.010 (0.009)	8.3
All sites – both areas	**62**	**591**	**37**	**85.7 (3.7)**	**0.037 (0.013)**	**0.019 (0.010)**	**0.048 (0.017)**	**0.007 (0.005)**	**19.4**

Table 2. Mann-Whitney test probabilities comparing mean total exposed abalone densities between index, fish farm and random sites in Queen Charlotte and Johnstone Straits in 2004. P-Values in bold indicate significant differences.

	Sites	
Sites	Index	Random
Queen Charlotte Strait		
Random	0.496	
Finfish aquaculture	0.437	0.085
Johnstone Strait		
Random	**0.001**	
Finfish aquaculture	**0.011**	0.540

Table 3. Recent total exposed abalone density estimates of index site surveys in British Columbia.

Location	Most recent survey year	Density Estimate	Mean Size (mm SL)	Reference
North and Central Coast	2001	0.27 ± 0.04	77.6	In preparation
Queen Charlotte Island	2002	0.34 ± 0.06	67.0	Atkins et al., 2004b
North-west Vancouver Island	2003	0.09 ± 0.04	59.1	Atkins and Lessard, 2004a
Queen Charlotte Strait	2004	0.06 ± 0.02	76.8	This paper
Johnstone Strait	2004	0.02 ± 0.01	109.9	This paper

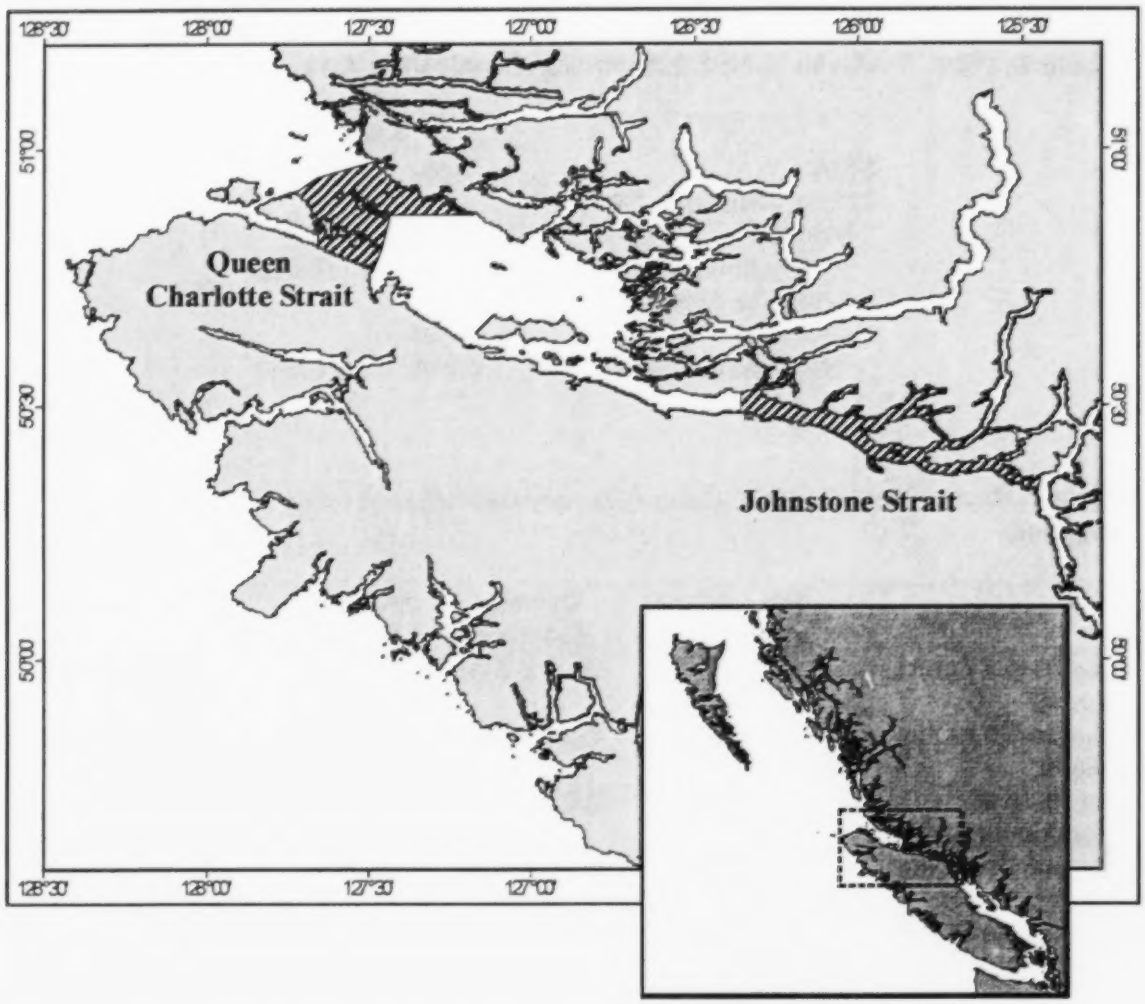

Figure 1. Map of Queen Charlotte Strait and Johnstone Strait, showing the two areas surveyed.

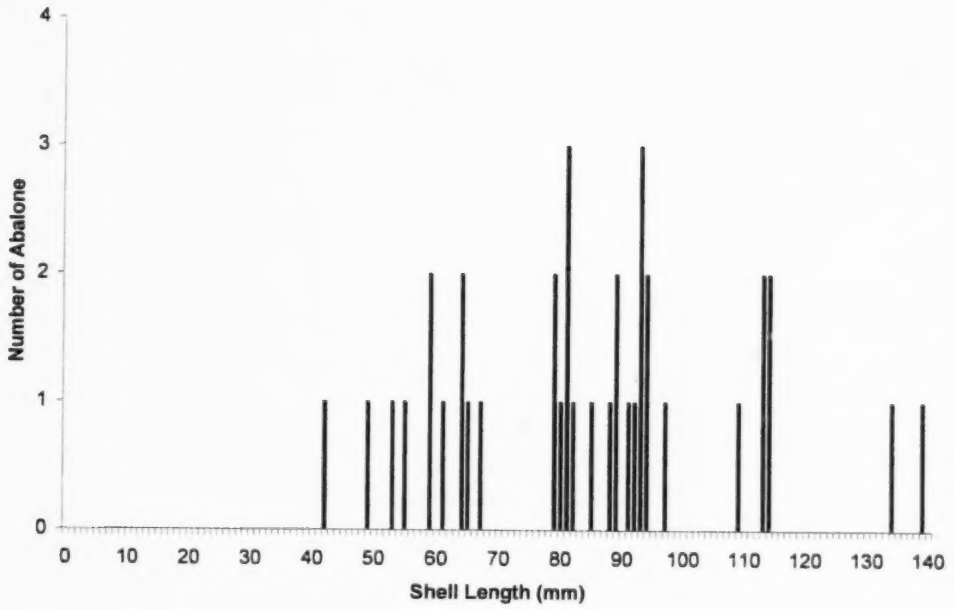

Figure 2. Size frequency distribution of exposed abalone from all sites surveyed in Queen Charlotte and Johnstone Straits, May 2004.

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Appendix 1. Dive survey summary for abalone and urchins by site, Queen Charlotte Strait, 2004.

Site	Date	Bottom Time	Slope (%)	# of Quadrats	Abalone		Urchins	
					Count	Density (#/m^2)	Count	Density (#/m^2)
Index sites								
I1	May 18	9	8	8	0	0.000	20	2.500
I2	May 18	17	30	16	2	0.125	98	6.125
I3	May 18	16	46	8	0	0.000	16	2.000
I4	May 18	23	39	7	0	0.000	34	4.857
I5	May 17	30	16	17	6	0.353	85	5.000
I6	May 17	21	19	8	0	0.000	16	2.000
Random sites								
R02	May 17	15	65	8	0	0.000	0	0.000
R03	May 18	9	72	8	0	0.000	27	3.375
R04	May 17	14	23	8	0	0.000	15	1.875
R06	May 17	19	11	16	2	0.125	248	15.500
R07	May 17	17	8	8	0	0.000	33	4.125
R08	May 18	8	61	8	0	0.000	21	2.625
R10	May 18	13	46	8	0	0.000	40	5.000
R11	May 18	8	27	8	0	0.000	0	0.000
R12	May 17	8	4	8	0	0.000	0	0.000
R15	May 17	20	16	15	1	0.067	56	3.733
R19	May 17	9	42	8	0	0.000	7	0.875
R20	May 18	25	29	16	2	0.125	147	9.188
R25	May 17	12	42	8	0	0.000	0	0.000
Finfish aquaculture sites								
F1	May 18	34	29	16	6	0.375	115	7.188
F2	May 18	13	69	8	0	0.000	17	2.125
F3	May 18	12	46	8	0	0.000	11	1.375
F5	May 18	10	34	8	0	0.000	20	2.500
F6	May 17	21	32	16	1	0.063	93	5.813
F7	May 17	28	27	16	3	0.188	117	7.313
F8	May 17	38	23	16	4	0.250	93	5.813

Appendix 2. Dive survey summary for abalone and urchins by site, Johnstone Strait, 2004.

Site	Date	Bottom Time	Slope (%)	# of Quadrats	Abalone		Urchins	
					Count	Density (#/m^2)	Count	Density (#/m^2)
Index sites								
I7	May 19	33	27	16	1	0.063	9	0.563
I8	May 19	23	23	16	8	0.500	0	0.000
I9	May 19	13	4	8	0	0.000	0	0.000
Random sites								
R26	May 20	13	38	8	0	0.000	0	0.000
R27	May 19	13	42	8	0	0.000	207	25.875
R28	May 19	24	36	16	1	0.063	372	23.250
R29	May 20	7	38	8	0	0.000	39	4.875
R33	May 19	8	72	8	0	0.000	78	9.750
R34	May 19	13	46	8	0	0.000	48	6.000
R35	May 19	10	61	8	0	0.000	130	16.250
R38	May 19	10	57	8	0	0.000	10	1.250
R40	May 19	24	61	8	0	0.000	3	0.375
R42	May 19	11	19	8	0	0.000	44	5.500
R43	May 19	13	23	8	0	0.000	0	0.000
R44	May 20	10	50	8	0	0.000	53	6.625
R46	May 20	11	50	8	0	0.000	44	5.500
R47	May 20	11	34	8	0	0.000	9	1.125
R48	May 20	8	46	8	0	0.000	66	8.250
R49	May 20	13	69	8	0	0.000	77	9.625
R51	May 19	15	69	8	0	0.000	1	0.125
R52	May 19	12	46	8	0	0.000	25	3.125
R53	May 19	11	65	8	0	0.000	44	5.500
R54	May 20	6	61	8	0	0.000	50	6.250
R55	May 19	14	46	8	0	0.000	0	0.000
R56	May 19	16	61	8	0	0.000	5	0.625
R57	May 19	10	53	8	0	0.000	7	0.875
R60	May 20	10	50	8	0	0.000	108	13.500
Finfish aquaculture sites								
F21	May 19	14	53	8	0	0.000	2	0.250
F22	May 19	14	38	8	0	0.000	0	0.000
F23	May 19	13	38	8	0	0.000	0	0.000
F24	May 19	13	72	8	0	0.000	5	0.625
F25	May 20	13	27	8	0	0.000	5	0.625
F26	May 20	15	42	8	0	0.000	204	25.500
F27	May 20	11	34	8	0	0.000	5	0.625
F28	May 20	13	30	8	0	0.000	118	14.750
F29	May 20	10	72	8	0	0.000	18	2.250

Appendix 3. Site descriptions of all 62 sites surveyed in Queen Charlotte and Johnstone Straits, May 2004. The most common substrates are listed (1 = first, 2 = second, 3 = third) where substrate code 1 = smooth bedrock, 2 = bedrock with crevices, 3 = boulders, 4 = cobble, 5 = gravel, 7 = sand, 8 = shell, 9 = mud. The algae are listed by growth characteristics for the most common (Sp 1) and second most common (Sp 2) with percentage cover (%) for each, where: AC = articulated corallines, AG = *Agarum* sp, AL = *Alaria* sp, BB = brown branched, CO = *Costaria costata*, CY = *Cymathere triplicata*, DE = *Desmarestia* sp, EG = *Egregia menziesii*, FU= *Fucus gardneri*, GH = green filamentous, GI = *Gigartina* sp, IR = *Iridaea* sp, LA = *Laminaria* sp., MA= *Macrocystis integrifolia*, NT = *Nereocystis luetkeana*, PH = *Phyllospadix* sp, PL= *Pleurophycus gardneri*, PO = *Porphyra* sp, PT = *Pterygophora californica*, RB = red branched, RF= red foliose, RH = red filamentous, UL = *Ulva* sp, ZO = *Zostera marina*.

Site	Substrate			Slope	Canopy		Understory				Turf				Encrusting
	1	2	3	%	Sp.	%	Sp.	%	Sp.	%	Sp.	%	Sp.	%	%
Queen Charlotte Strait															
I1	3	7	4	8							UL	20	BB	20	75
I2	1	2	3	30			LA	20			AC	15	BB	10	80
I3	3	1	8	46	NT	10	DE	20	AL	10	AC	5	IR	5	80
I4	3	8	1	39	NT	5	DE	20	AL	10	AC	5			80
I5	1	2		16	NT	10	DE	50	PT	10	AC	10			80
I6	2	3	8	19	NT	40	PL	50	AG	50	AC	30			80
R2	2	1	3	65	NT	80	PT	30	CY	25	AC	50	RF	40	80
R3	2	1	8	72			PH	40	LA	20	AC	30	RB	20	100
R4	8	1	4	23	MA	50	DE	60	AL	40	AC	20			10
R6	2	1		11	NT	5	PH	10			AC	5			100
R7	1	2		8	NT	10	DE	80	PH	20	AC	20			80
R8	1	2	3	61			LA	50	PH	40	RB	50			100
R10	1	2		46			PH	10	AG	5	AC	5			90
R11	1	3	8	27			LA	50	DE	30	BB	40	UL	20	60
R12	3	1	2	4			EG	20	LA	20	UL	50	FU	40	90
R15	3	2	4	16	NT	20	LA	30	CY	30	UL	40	BB	30	60
R19	8	1	2				LA	35	CY	35	UL	35	BB	35	80
R20	1	2	3	29			RH	15	DE	10	PH	10	AC	5	25
R25	1	8	7	42	NT	40	LA	60	BB	40	BB	70			100
F1	2	1	3	29			PT	100			DE	10			100
F2	1	2		69			PT	75	LA	50	AC	15			90
F3	1	7		46	LA	50	ZO	10			AC	75			95
F5	1	2	8	34	NT	10	DE	30	AL	20	UL	30	BB	30	90
F6	1	2	3	32	NT	5	DE	10							70
F7	1	2	8	27	NT	10	DE	60			AC	5			80
F8	1	2		23	NT	20	DE	80	PH	20	AC	10			80
Johnstone Strait															
I7	3	1	8	27	NT	25	AL	50	LA	50					75
I8	1	8	4	23	NT	10	LA	25	AG	25					50
I9	4	7	8	4	NT	20	AL	25	LA	25	UL	5			5
R26	9	3	4	38	NT	10	ZO	60	AG	40	UL	10			10
R27	1	2	3	42							GH	15	AC	15	40
R28	1	2	3	36			AG	15			AC	15			70
R29	3	9	8	38	NT	20	AL	30							40
R33	1	2	8	72											75
R34	3	4	5	46			LA	5			UL	5			90

Appendix 3. Con't.

Site	Substrate			Slope	Canopy		Understory				Turf				Encrusting
	1	2	3	%	Sp.	%	Sp.	%	Sp.	%	Sp.	%	Sp.	%	%
R35	1	2		61	NT	10					BB	30	AC	20	100
R38	2	1	3	57							RB	20	AC	10	80
R40	2	1	3	61	NT	100	AG	100	CO	100	LA	100			15
R42	1	3	2	19							GH	20	UL	20	50
R43	3	8	2	23	NT	20	CO	50	LA	50	UL	10	ZO	10	30
R44	9	3	2	50	NT	80	AL	40	DE	20	UL	5			30
R46	1	3		50			DE	5			UL	10			5
R47	3			34	NT	30	AG	40	LA	20	UL	20	RB	20	50
R48	1	2	3	46	NT	5	AG	30			UL	10			90
R49	1	2		69			AL	10	DE	10	AC	5			90
R51	1	2	8	69	NT	50	AL	50	AG	50	AC	25	UL	25	35
R52	3	4		46			AL	30			RB	30			80
R53	3	2	1	65			AL	60	CO	20					90
R54	1	2	3	61	NT	10	AL	30	DE	20					90
R55	1	8	2	46	NT	30	AG	80	LA	40	UL	20			30
R56	1			61	NT	15	CO	50	AG	50					50
R57	1	2		53	NT	5	AL	30	CO	10	UL	10	AC	5	80
R60	2	1		50	NT	5	AL	20	BB	20	UL	10			90
F21	2	1	8	53			AG	100	LA	80	UL	10			50
F22	1	8	2	38	NT	15	AG	100	LA	100	UL	20			30
F23	8	3		38	NT	5	LA	70	AG	70	UL	5			30
F24	1	2	8	72	NT	5	LA	50	CO	50					60
F25	1	8		27	NT	10	AG	20	CO	20	UL	10			40
F26	3	4		42			AG	10	RB	5					50
F27	1	2		34			AL	10	DE	5	UL	5			10
F28	3	1	2	30			GI	1			AL	1			60
F29	1	2	3	72			AG	90	CO	10	PO	20	IR	5	90

Appendix 4. Density for exposed abalone by size category for each site surveyed in Queen Charlotte and Johnstone Straits, May 2004.

Site	Number of Quadrats	Total number of abalone	Density of Exposed Abalone by Size Category (mm SL)			
			<70	≥70	≥100	Total
Queen Charlotte Strait						
I1	8	0	0.00	0.00	0.00	0.00
I2	16	2	**0.06**	**0.06**	**0.06**	**0.13**
I3	8	0	0.00	0.00	0.00	0.00
I4	7	0	0.00	0.00	0.00	0.00
I5	17	6	**0.29**	**0.06**	0.00	**0.35**
I6	8	0	0.00	0.00	0.00	0.00
R2	8	0	0.00	0.00	0.00	0.00
R3	8	0	0.00	0.00	0.00	0.00
R4	8	0	0.00	0.00	0.00	0.00
R6	16	2	0.00	**0.13**	0.00	**0.13**
R7	8	0	0.00	0.00	0.00	0.00
R8	8	0	0.00	0.00	0.00	0.00
R10	8	0	0.00	0.00	0.00	0.00
R11	8	0	0.00	0.00	0.00	0.00
R12	8	0	0.00	0.00	0.00	0.00
R15	15	1	0.00	**0.07**	0.00	**0.07**
R19	8	0	0.00	0.00	0.00	0.00
R20	16	2	0.00	**0.13**	0.00	**0.13**
R25	8	0	0.00	0.00	0.00	0.00
F1	16	6	**0.13**	**0.25**	0.00	**0.38**
F2	8	0	0.00	0.00	0.00	0.00
F3	8	0	0.00	0.00	0.00	0.00
F5	8	0	0.00	0.00	0.00	0.00
F6	16	1	**0.06**	0.00	0.00	**0.06**
F7	16	3	**0.06**	**0.13**	0.00	**0.19**
F8	16	4	**0.06**	**0.19**	0.00	**0.25**
Johnstone Strait						
I7	16	1	0.00	**0.06**	**0.06**	**0.06**
I8	16	8	0.00	**0.50**	**0.25**	**0.50**
I9	8	0	0.00	0.00	0.00	0.00
R26	8	0	0.00	0.00	0.00	0.00
R27	8	0	0.00	0.00	0.00	0.00
R28	16	1	0.00	**0.06**	**0.06**	**0.06**
R29 to R60	8	0	0.00	0.00	0.00	0.00
F21to F29	8	0	0.00	0.00	0.00	0.00